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DYNA SOAR RESEARCH OBJECTIVES

by

FRANK R. ANDERTON Jr.

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SUMMARY

The research objectives of the Dyna Soar hypersonic glider are reviewed and the flight regime from which data will be obtained is presented in comparison with current manned space projects. The development of the glider through ground testing and research is outlined and areas in which significant technical advances will be made are pointed out. The flight test program is described in general with reference made to specific test objectives.

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Après un rappel des buts des recherches effectuées sur le planeur hypersonique, Dyna Soar, l'auteur expose les conditions de vol à partir desquelles seront obtenus les résultats visés, en établissant une comparaison avec celles pour les appareils pilotés actuels destinés aux recherches spatiales. Il indique les grandes lignes pour la réalisation du planeur à la suite d'essais au sol et d'études, et signale les domaines dans lesquels des progrès techniques importants sont à attendre. Une vue d'ensemble du programme d'essais en vol prévu est présentée avec mention des buts particuliers visés par les vérifications à effectuer.

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Frank R. Anderton, Jr.*

The exploration of the flight regime of the hypersonic glider is vital to the space program of the United States, for man cannot safely venture into uncharted space until he has conquered the many varied problems of re-entry into the Earth's atmosphere. Manned exploration of our solar system, for instance, demands that technology assure safe recovery of the space vehicle and its crew.

The winged hypersonic glider, because of its flexibility and maneuverability within the atmosphere, will undoubtedly be the configuration of many future space systems. The mission to be fulfilled by the Dyna Soar glider will provide data which will ultimately decide the design of these manned recoverable space vehicles. Dyna Soar's necessity is therefore evident; without it, man's future in space exploration, beyond a few random ventures, becomes difficult and obscure.

Figure 1 will help to show the place which Dyna Soar holds in the exploration program. Shown are the altitude-velocity flight regimes of the X-15, Mercury capsule, and Dyna Soar hypersonic glider. The X-15 will provide the first evaluation of the problems of hypersonic flight, for it is capable of duplicating, on a limited scale, many of the problems of space flight. Its primary purpose is to obtain data on the aerodynamic heating and stability and control problems attendant with space flight and re-entry to the atmosphere. In comparison with the large design flight envelope of the X-15, the Mercury capsule flight corridor is shown as a single line. This is because its re-entry trajectory, once established by firing of the retro-rockets, will be essentially invariable. That is, the pilot will have control over the vehicle's attitude in space but little or no effective control over its performance. Primarily, the Mercury capsule will investigate, for the first time, the problems of orbital flight including man's physiological reactions and ability to perform tasks while in a prolonged zero-'g' space environment. The Dyna Soar will have orbital speed capability, as will Mercury, but, due to its winged configuration which allows it to generate aerodynamic lift, can also maneuver in three directions. By flying at various lift coefficients and bank angles it can control the distance to be flown and maneuver laterally to a preselected course. All of this adds up to flexibility in selecting and maneuvering to a particular landing site.

The overall objective of the Dyna Soar program is to exploit the inherent potential of the atmosphere for future hypersonic and orbital vehicles.

During the program being planned, the hypersonic flight corridor will be explored through the area of critical aerodynamic heating.

Specific objectives of the program are to:-

1. Explore the hypersonic flight regime
2. Explore maneuvering capabilities
3. Effect a conventional landing
4. Evaluate man's capabilities.

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The magnitude of the research program to be undertaken is vast. Consider, for instance, that it will be necessary to design and fabricate special-purpose bolts for Dyna Soar which can carry loads uniformly yet be resistant to the extreme temperatures to be encountered during hypersonic flight. In this way, the development of the glider vehicle as well as the results to be obtained from flight test will progress the state-of-the-art of space vehicles. It would be impossible to mention here all the advancements which will occur during the Dyna Soar program. Only some of the more significant and interesting facets of the research program will therefore be elaborated.

The nature of hypersonic fluid flow is something of which little was known a few years ago. Significant advancements have been made since then, of course, but there are many perplexing problems yet unsolved. Mathematical description of hypersonic flow is a difficult problem, especially when real gas effects, viscosity, and vehicle configuration are considered. Present theoretical and empirical expressions allow only approximate solutions; it has therefore become necessary to rely upon wind tunnel data for evaluation of the hypersonic flow field parameters. Correct evaluation of these parameters is absolutely essential, since the determination of the vehicle performance and aerodynamic heating characteristics rests upon their validity. An extensive free flight model and wind tunnel test program is therefore scheduled which is roughly three times more extensive than has been expended to date on the X-15. These tests will take place in at least five different tunnels. That is, the same test will be repeated in five different tunnels so that the limitations of any one tunnel, such as limited Reynolds number, can be eliminated from the data, thus assuring the greatest obtainable accuracy.

The wind tunnel test program involves tests at supersonic, transonic, and subsonic speeds as well as tests at hypersonic speeds. The transonic tests are of particular interest because of the compromises made in this regime to provide satisfactory aerodynamic characteristics at hypersonic speeds. A considerable wind tunnel test effort has been expended already by government agencies and the vehicle prime contractor - Boeing Airplane Company. These tests have led to the configuration which presently characterizes Dyna Soar.

Although it is possible to predict aerodynamic heating rates more accurately than hypersonic pressure distributions, for instance, it is still necessary to devote a great deal of wind tunnel testing to the verification of predicted heating results. This is particularly true because aerodynamic heating rates and surface temperatures are difficult to predict in the presence of non-equilibrium flow conditions, that is, when ionized or dissociated flow is present. The sensitivity of aerodynamic heating rates and temperatures to ionized flow is demonstrated by the fact that only one ionized atom in a thousand is enough to affect aerodynamic heating data. Since, in global flight, the Dyna Soar will fly in non-equilibrium thermodynamic conditions for more than 80% of its total flight time, wind tunnel verification of heating rates and temperatures is mandatory.

The design of a control system for a hypersonic glider is a difficult task because of the wide range of speed and altitude through which the vehicle operates. The lack of aerodynamic damping at high Mach numbers and the problem of low efficiency of aerodynamic controls with the vehicle's long-period motion at low aerodynamic pressures combine to make vehicle control at high speeds and altitude difficult. In addition, there are severe cross-coupling effects attendant with the high angles of attack which are characteristic of Dyna Soar.

As in the case of aerodynamics and thermal heating, the degree of confidence which can be placed in theoretical calculations requires that stability and control characteristics be thoroughly investigated in wind tunnels and with free flight models. Problems other than the determination of stability derivatives, such as investigation of cross-coupling effects and the integration of reaction and aerodynamic controls, can be examined on flight simulators. Information from the X-15 flight test program will be helpful also since the X-15 will investigate the region of low dynamic pressure and will derive information on the operation of ballistic or reaction control systems.

In essence, the stability and control problem cannot be isolated from those of fluid flow and aerodynamic heating. The determination of stability derivatives, for instance, is dependent upon pressure distributions, which are in turn dependent upon fluid flow properties. In a similar fashion the structural deflections caused by aerodynamic heating will change stability and control characteristics.

The net effect upon vehicle configuration of the interactions and simultaneous requirements of performance, aerodynamic heating, and stability and control is design compromise. In many cases it appears impossible to meet two sets of conflicting requirements at the same time.

For instance, nose cone and leading edge diameters should be as small as possible to minimize drag; but should be as large as possible to minimize temperature.

Such problems can only be dealt with by design compromise. One of the objectives of the free flight and wind tunnel test programs must necessarily be to sophisticate these design compromises as well as to verify theoretical calculations. Of course, final exact results will have to come from the flight test program. Flight test is necessary since wind tunnel data can never exactly duplicate the conditions encountered in free flight. In addition, there are many phases of the research program which cannot be accomplished on the ground.

The flight test program which has been planned consists essentially of three phases: an air-launched phase, an unmanned ground launch phase, and a manned ground launched phase. The program has been designed to provide timely results with the greatest safety and degree of confidence in each flight, to give the greatest probability of data acquisition and recovery, and to make the greatest use of the capabilities of the vehicle's pilot.

The air-launched phase has as its main objectives the demonstration of subsystem operation, vehicle handling qualities, landing characteristics and structural integrity. Inherent in these objectives is the determination of vehicle lift-drag characteristics, stability augmentation system operation, center of pressure shift, and stability and control.

The air-launched phase, which will take place at Edwards Air Force Base, is to be conducted much in the same manner as the X-15 flight test program. Dyna Soar will be dropped from a B-52 mothership and, with the help of a small rocket engine, reach supersonic speeds. This speed regime allows the investigation of low supersonic stability and control characteristics, trimmability, and maneuvering capabilities. The effects of limited pilot visibility and vehicle ~~static~~ stabil~~ity at low speed~~ upon the landing characteristics will also be investigated.

The unmanned ground launch phase has as its main objectives the functional and structural demonstration of the booster glider combination and the evaluation of the escape systems. The vibration and noise environment will also be evaluated at this time and measurements of temperature and pressure will be taken from both the booster and vehicle during the boost trajectory.

Also an important part of the unmanned program is the demonstration of separation characteristics; that is, separation of the second stage of the booster from the first, and separation of the vehicle from the second stage. The booster trajectory to be flown on the first manned flights will be confirmed by unmanned firings and, if feasible, the vehicle will be glided in the flight corridor after separation from the booster in order to obtain performance, aerodynamic heating, and stability and control data prior to the manned firings.

The manned ground-launched program consists of a series of flights in which the booster burn-out velocity is incrementally increased as the program proceeds. The flights are planned to explore the stability and control and thermodynamic flight corridor boundaries in a systematic and progressive manner so that maximum safety and confidence in each flight can be maintained. This concept also allows for maximum exercise of the pilot's decision-making capabilities.

During the manned program, data such as pressure, temperature, velocity, altitude and so on will be obtained. This information will lead to the verification or modification of present theories and will illuminate strengths and weaknesses in Dyna Soar system design. As such, this information will be of great interest to Dyna Soar's design engineers as well as to the designers of future space vehicles. The data obtained from flight test will reveal the effectiveness of the vehicle structure and material, will define the limits of the flight corridor, the maneuvering and performance capability, stability and control characteristics and the effectiveness of the reaction and aerodynamic controls. One of the Dyna Soar's main objectives, the determination of man's contribution of discretionary judgement to achieve optimum performance and reliability, will also be achieved during flight test, as will an evaluation of the vehicle's subsystems such as the guidance, energy management and communications subsystems.

During the flight test program, Dyna Soar will also serve as a test bed for a variety of geophysical experiments. There have been proposed a number of experiments to determine upper atmosphere density, pressure, temperature and composition as well as meteorite and geomagnetic measurements. It has also been suggested that Dyna Soar be used to make cosmic ray studies, solar observations, radiation measurements, and upper atmosphere electrical structure measurements.

Dyna Soar's payload capability and possibility of flight tract variation make it a useful vehicle for geophysical measurements. Being a winged vehicle, it depends on lift and therefore is a very useful platform for making upper atmospheric measurements. Some measurements, such as density, shape of the earth, and geopotential field measurements, have a direct bearing on the flight test program, since they can affect Dyna Soar performance, espacially at high velocity. Other measurements such as cosmic ray and radiation measurements may have an effect upon both the vehicle and the pilot. Many of these experiments are important from the standpoint that their results may place limitations upon the operating characteristics of the vehicle.

It is hoped that some small insight to the scientific objectives of the Dyna Soar program has been provided. The magnitude of the exploratory program is unquestionably enormous but its necessity is equally unquestionable. At the present time, it seems a vast undertaking. In retrospect, twenty years from now, we shall wonder why we thought it so difficult.

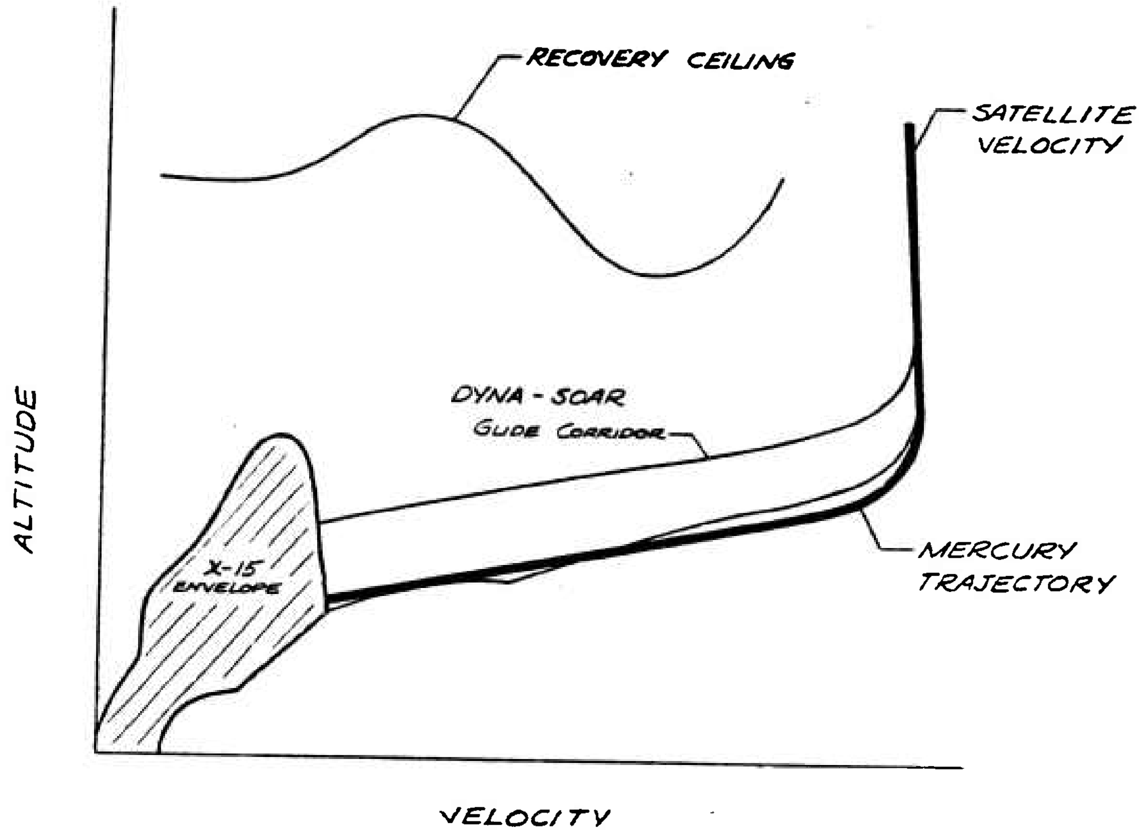

Fig. 1. Dyna Soar's part in the exploration program

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